

Nutrient Management Technical Note
from
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Using Harvest Data to Calculate Nitrogen Removal



The following technique can be used to calculate nitrogen removal by field crops. It is useful to those farms that are required to track nitrogen inputs and outputs under direction from the New Mexico Environment Department. The approach should not be used to make fertilizer recommendations for a succeeding crop. Soil testing must be done prior to planting to determine fertilizer and manure loading rates. A beginning season soil test prior to fertilizing or applying manure is needed in order for this method to be valid.

All crops use nutrients from the soil in order to grow and develop. Nitrogen is often the most limiting nutrient in crop production as it is needed in the greatest quantity. Nitrogen in the form of nitrate can be easily leached through the soil profile and away from the crop root zone. How much nitrogen a crop has used can be determined from crop yield data and protein or nitrogen concentration of the plant tissue. Yield data, expressed as tons per acre, is calculated from total tons of crop harvested from the field divided by the acreage (equation 1). Yield reported by commercial harvesters is usually total tonnage per field. If the acreage is known then yield per acre can be determined from this data. The reported tonnage is "as harvested", or from a moist condition. Corn for silage is often harvested at 68 - 72% moisture. All nutrient removal data must be determined from the quantity of dry matter removed from the field. Dry matter is determined by multiplying the yield by the fraction of dry matter (equation 2). Dry matter can be determined from moisture content by subtracting the percent moisture from 100. Take the result, divide by 100, multiply by wet yield per acre and the dry matter yield is obtained (equation 2).

(1) "wet" tons per acre = harvested tons ÷ field acreage

(2) dry matter yield (tons per acre) = ((100 - %moisture) ÷ 100) × yield per acre

Most dairies and farmers determine the crude protein of the harvested material if it is corn, sorghum, wheat, oats, barley, alfalfa, or other forage. The nitrogen concentration of the crop is directly related to the crude protein content by a factor of 6.25. Crude protein percentage should be divided by 6.25 in order to determine the nitrogen concentration in the harvested material. Alternatively, plant tissue analysis for total nitrogen content of the plant material can be done by many laboratories. Total nitrogen content of plant tissue is usually expressed as a percentage. If nitrogen content is expressed in mg kg⁻¹ or parts per million divide that number by 10,000. Nitrogen removal (equation 3) can then be calculated by dividing the nitrogen concentration (%) by 100 and multiplying by yield (equation 1). The result of equation 3 then needs to be converted to pounds per acre by multiplying by 2000 (the number of pounds per ton).

(3) *N removal (lb per acre)* = ((%crude protein ÷ 6.25) ÷ 100) × equation 2 × 2000 lb per ton

Nitrogen removal by the crop is a function of what was in the soil prior to planting and what was applied during the growing season. A soil test should always be taken at the beginning of the season to determine how much additional nitrogen needs to be added during the season. Soil should be sampled in two depth increments referred to as topsoil and subsoil. The topsoil is often considered as the depth of plowing or disking. An 8-inch plow layer is common but can often

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extend to 12-inches. The subsoil is considered as some depth increment below the plow-layer. The depth for subsoil sampling should be between 12- and 24-inches. Many yield response curves utilize the average soil test nitrogen values up to a 24-inch depth.

Two tests that need to be determined on the soil prior to planting or adding fertilizer or manures are soil organic matter and soil inorganic-N. Inorganic nitrogen is necessary for plant uptake and is usually in the form of nitrate-N and ammonium-N. Some laboratories will extract soil with 2M potassium chloride and reduce the ammonium-N to nitrate-N and report the total inorganic nitrogen as nitrate. Organic matter in New Mexico soils will usually contribute about 30 pounds of nitrogen per acre per percent of organic matter to a crop during the growing season under irrigated conditions. More or less nitrogen is mineralized from organic matter depending on the soil temperature and soil moisture. Organic matter need only be determined in the topsoil. Both the topsoil and subsoil should have inorganic nitrogen content determined.

The available soil nitrogen at the beginning of the season needs to be accounted for in order for this method to work. Available nitrogen is determined from the following equation:

$$(4) \quad \text{available soil N} = \text{Inorganic N (lb/Acre)} + (30 \text{ lb N/Acre} \times \% \text{ Organic Matter})$$

Soil test results are reported as available nitrogen in pounds per acre but more often will be reported in parts per million (ppm) or milligrams per kilogram (mg/kg) of soil. In order to convert milligrams per kilogram or parts per million to pounds N per acre the soil bulk density should be known. The following equation can be used to estimate pounds N per acre when given a soil texture and two foot average soil nitrate concentration expressed in parts per million or mg per kg:

$$(5) \quad \text{lb N per acre} = (\text{ave profile N mg/kg}) \times \left\{ \begin{array}{l} 4.8 \text{ for sand} \\ 4.3 \text{ for sandy loam} \\ 3.8 \text{ for loam} \\ 3.7 \text{ for clay loam} \\ 3.4 \text{ for clay} \end{array} \right\} \div 12 \text{ inches} \times \text{sampled soil depth (inches)}$$

The New Mexico Water Quality Control Commission (NMWQCC) has mandated that effluent will be applied based on the total nitrogen content of the effluent. The maximum application rate of the effluent should not exceed 1.25 times the crop nitrogen removal. However, in order to assure minimum losses of nitrogen, the beginning available soil nitrogen should be subtracted from the crop nitrogen removal before calculating the quantity of effluent that should have been applied. For example, a soil test was performed on a clay loam soil and was found to contain 1.5% organic matter and 10 mg/kg (which is the same as ppm) inorganic nitrogen. The nitrogen contribution from organic matter to the crop for the season will be 45 pounds N per acre (1.5% organic matter multiplied by 30 lb N per acre). The inorganic nitrogen in the soil can then be added to the contribution from organic matter. A clay loam soil that contains an average of 10 ppm of inorganic nitrogen in the top 2 feet will have 74 pounds N per acre as calculated with equation 5. The total nitrogen available to the plant for the season without anything added will come close to 119 pounds N/A. This amount of nitrogen can be subtracted from the total removed by the plant. The remainder is what has to have come from added fertilizer (equation 6).

(6) $\text{Additional N needed} = \text{Plant uptake (lb/acre)} - \text{initial soil nitrogen (lb/acre)}$

Suppose a crop of corn was determined to have removed 350 pounds of nitrogen per acre. The soil would have provided 119 pounds per acre therefore an additional 231 pounds N had to come from fertilizer applications. Unfortunately, fertilizer is not 100 percent efficient at supplying all the added nitrogen to the plant. This is known as fertilizer efficiency. Synthetic fertilizers are doing good to have an efficiency of 40% to 60%. In other words, if 100 pounds of nitrogen were applied then 40 to 60 pounds would actually be used by the plant. It is no different for organic sources of nitrogen. The process by which organic nitrogen becomes available to plants is called mineralization. Under the right conditions of soil temperature and soil moisture, 25% to 45% of the applied organic nitrogen can be mineralized and become available to plants. On average, 35% of the applied organic nitrogen can become available to the plant. This efficiency has to enter into the cookbook approach to nutrient management.

In the example, an additional 230 pounds of nitrogen per acre had to have become available from applied lagoon effluent. Lagoon effluent contains both organic and inorganic N. The amount of organic nitrogen added needs to account for the N that will become available (mineralize) during the growing season. Effluent from lagoons also has an inorganic fraction that varies from 45 to 55% of the total nitrogen. If, on average, half of the total nitrogen in effluent is inorganic nitrogen, then 115 lb of nitrogen can be supplied by effluent directly. An additional 115 pounds of nitrogen needs to have been mineralized from the organic fraction. In order to get this 115 pounds of nitrogen then 329 pounds of organic nitrogen must have been added in order for the additional nitrogen to be mineralized and made available to the plant (equation 7).

(7) $N \text{ from organic fraction} = 230 \text{ lb/acre} \div 35\% / 100$

How much lagoon effluent does this equal? The total nitrogen supplied by the effluent needs to be 444 pounds of nitrogen per acre (115 + 329). Ideally, the effluent nitrogen content would be known through proper testing. If we suppose the median nitrogen content of lagoon effluent is 500 mg of total nitrogen per liter, then 106,654 gallons of effluent per acre would need to be applied to the soil in order to supply the needs of the plant (equation 8).

(8)
$$\frac{\text{effluent gallons}}{\text{acre}} = \frac{1 \text{ gallon}}{3.78 \text{ L}} \times \frac{1 \text{ L effluent}}{500 \text{ mg N}} \times \frac{1000 \text{ mg}}{\text{g}} \times \frac{454 \text{ g}}{\text{lb}} \times \frac{444 \text{ lb N}}{\text{acre}}$$

This is equivalent to 3.9 acre-inches of effluent (recall there is 326,700 gallons per acre foot). This is not enough water to irrigate most crops therefore supplemental water must be supplied to meet the water demand of the intended crop.

As time marches on and more effluent applications are made there will be a gradual buildup of organic matter and residual nitrate-N in the soil. Soil testing will reflect this buildup and necessitates an adjustment of the application rate to meet the crop needs and maintain some degree of environmental protection from N leaching.

The following table summarizes all the equations into a simple worksheet.

Effluent application rate calculations when effluent is the only source of nitrogen to a crop.

A	B	C	D§	E	F‡	G¶	H†	I	J††	K\$
Field	Planted area	Wet tonnage	Dry Matter	Crude Protein	Soil O.M.	Soil Inorg. N	Effluent TKN + NO ₃ -N	Mineralization rate	N removal	Effluent Volume Needed per acre
	Acres	tons/field	%	%	%	lb/A	mg/L	%	lb N/A	gallons inches
corn 1	60	1500	24	18	1.5	125	650	35	346	108,929 4.0

§ % Dry matter is equal to 100 - % moisture.

‡ There is typically 30 pounds N/A released per percent organic matter in the soil during the growing season.

¶ Inorganic N in pounds per acre is calculated from the equation given below.

† Effluent TKN is approximately 50% ammonium-N and 50% organic-N. Nitrate-N is usually not detectable or very low.

†† Plant Nitrogen Removal = (column C/column B)*(column D/100)*(column E/6.25/100)*2000

\$ effluent volume per acre = (((column J-(column F*30+column G))*454*1000/column H/3.78)*0.5)+(((column J-(column F*30+column G)) * 454 * 1000/column H/3.78) / (column I/100))

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